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**Bank capital, the state contingency of
banks' assets and its role for the
transmission of shocks**

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Non-technical summary

Research Question

Recent macroeconomic models heavily emphasize the role of bank capital as a propagation channel of shocks which results from a financial contracting problem between banks and their creditors and amplifies shocks to the real economy. Since bank capital is an important determinant of banks' leverage, which in turn affects how shocks are propagated through the banking sector to the real economy, it is important to put the focus on the channels which determine the evolution of bank capital in a macroeconomic context. In particular, it is of interest to understand how the structure of assets in banks' balance sheets affects banks' profits and therefore ultimately macroeconomic dynamics.

Contribution

This paper contributes to the discussion concerning how bank capital affects economic dynamics. It investigates the composition of banks' balance sheets to determine how this composition affects the propagation of macroeconomic shocks. We allow for a non-state-contingent asset with a constant price of unity and a state-contingent asset which is traded on a market and consequently exhibits a market-determined price. We show how the evolution of bank capital depends on the share of non-state-contingent assets in banks' balance sheets and present the consequences for macroeconomic dynamics by applying a New Keynesian dynamic stochastic general equilibrium model.

Results

State-contingent securities impact on banks' balance sheets through changes in their returns (and their prices), which depend on the state of the economy. Non-state-contingent assets are signed before shocks are realized and their repayment is guaranteed. For this reason they insulate banks' balance sheets from recent economic activity in the absence of defaults. Our results show that non-state-contingent assets in banks' balance sheets attenuate the amplification of shocks resulting from financial frictions in the banking sector.

Nichttechnische Zusammenfassung

Fragestellung

In aktuellen makroökonomischen Modellen mit Finanzsektor wird die Rolle von Bankkapital als ein Übertragungskanal bei ökonomischen Schocks stark betont. Die Lösung eines Kontraktproblems zwischen Banken und ihren Kreditgebern führt zu einer Verstärkung der Übertragung von Schocks auf die Realwirtschaft. Da Bankkapital ein Einflussfaktor des Verschuldungsgrades ist und dieser die Übertragungseffekte von Schocks über den Bankensektor auf den Realsektor maßgeblich beeinflusst, ist es von Interesse, den Fokus auf die Untersuchung der Kanäle zu lenken, die in einem makroökonomischen Kontext die Entwicklung des Bankkapitals beeinflussen. Im Besonderen interessiert hierbei, welche Rolle die Eigenschaften der gehaltenen Aktiva beim Aufbau von Eigenkapital spielen und welche Rückwirkungen sich auf die makroökonomische Entwicklung hieraus ergeben.

Beitrag

Dieses Papier trägt zu der Diskussion bei, wie die ökonomische Aktivität von der Entwicklung des Eigenkapitals der Bank beeinflusst wird und stellt hierbei auf die Zusammensetzung der Aktiva der Bank ab. In diesem Zusammenhang wird auf eine Bank zurückgegriffen, die zwei Vermögensobjekte hält: einerseits ein Vermögensobjekt, dessen Ertrag von der aktuellen ökonomischen Entwicklung abhängig ist, und andererseits ein Vermögensobjekt, dessen Ertrag hiervon unabhängig ist. Um die Auswirkungen auf das Eigenkapital der Bank sowie auf die gesamtwirtschaftliche Entwicklung zu zeigen, wird ein Neu-Keynesianisches stochastisches allgemeines Gleichgewichtsmodell herangezogen und der Anteil der jeweiligen Vermögensobjekte variiert.

Ergebnisse

Vermögensobjekte, deren Ertrag in erster Linie von der aktuellen ökonomischen Aktivität abhängt, beeinflussen den Aufbau des Eigenkapitals der Bank durch die Veränderung der Renditen (sowie deren Preise). Hingegen schirmen Vermögensobjekte, die nicht von der aktuellen Entwicklung der Wirtschaft abhängen, die Bank von ihr ab, da die Konditionen dieser Finanzaktiva in der Periode (oder den Perioden) zuvor festgeschrieben worden sind. Aus diesem Grund schwächt sich der bekannte durch Bankkapital vorhandene Verstärkungsmechanismus bei Schocks ab, wenn letztere Finanzaktiva in der Bilanz der Bank dominieren.

Bank Capital, the State Contingency of Banks' Assets and Its Role for the Transmission of Shocks*

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Abstract

The role of bank capital as a propagation channel of shocks is strongly pronounced in recent macroeconomic models. In this paper, we show how the evolution of bank capital depends on the share of non-state-contingent assets in banks' balance sheets and present the consequences for macroeconomic dynamics. State-contingent securities impact on banks' balance sheets through changes in their returns (and their prices), both of which depend on the current state of the economy. Non-state-contingent assets are signed before shocks are realized and their repayment is guaranteed. For this reason they insulate banks' balance sheets from recent economic activity in the absence of defaults. Our results show that non-state-contingent assets in banks' balance sheets attenuate the amplification of shocks resulting from financial frictions in the banking sector.

Keywords: Bank capital, state-contingent assets, non-state-contingent assets, monetary policy, financial frictions.

JEL classification: E44, E58, E61.

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1 Introduction

An erosion of bank capital during the 2007-09 financial crisis has been one of the essential features of this episode, and the resulting need for banks to delever has contributed significantly to the Great Recession (Brunnermeier, 2009). A reduction in bank capital increased the leverage ratio, making banks' balance sheets more vulnerable to new adverse shocks and thereby constraining banks' ability to obtain external funds. A cut in credit supply was the consequence which fed back to the real economy and eventually amplified developments which had originated in the real sector. Nearly twenty years ago, a shortage of bank capital was also one of the main drivers behind the "credit crunch" (or "capital crunch") in the USA at the end of the 1980s and the beginning of the 1990s, which largely contributed to the recession at that time (Bernanke and Lown, 1991). The propagation channel behind these developments largely stems from a general financial contracting problem between banks and their creditors (see Christiano and Ikeda, 2013, for example). Banks' leverage constraint generally affects the business cycle and amplifies developments in a downturn. This is the reason why recent macroeconomic models heavily emphasize the role of bank capital as a propagation channel of shocks to the real economy (Chen, 2001; Gerali, Neri, Sessa, and Signoretti, 2010; Gertler and Karadi, 2011; Meh and Moran, 2010; Zeng, 2013).¹

Since bank capital is an important determinant of banks' leverage, which in turn affects how shocks are propagated through the banking sector to the real economy, it is also important to put the focus on the channels which determine the evolution of bank capital in a macroeconomic context. If banks' balance sheets are dominated by assets which are traded on a market, asset price changes will mainly affect the evolution of bank capital (Gertler and Karadi, 2011, 2013). A drop in asset prices weakens bank capital and increases banks' leverage. Non-market-based assets might entail different effects because the price effect is missing (Kühl, 2014; Rannenberg, 2013). In this case, changes in asset returns predominantly affects banks' profits, which translates into the evolution of bank capital. Furthermore, the state contingency of assets is expected to be an important driver for bank capital. While the returns (and prices) on a state-contingent asset depend on the current state of the economy, this is not the case for non-state-contingent assets. From this point of view, it is of interest to understand how the structure of assets in banks' balance sheets affect banks' profits, which determine bank capital and banks' leverage ratio, and therefore macroeconomic dynamics in the end. The use of a dynamic macroeconomic model with a banking sector is best suited to scrutinize these interdependent effects.

This paper contributes to the discussion concerning how bank capital affects economic dynamics. By using a New Keynesian dynamic general equilibrium model, we investigate the composition of banks' balance sheets in order to gain insight how this composition affects the propagation of macroeconomic shocks to the real economy. Concretely, we show how the evolution of bank capital depends on the share of non-state-contingent assets in

¹Alternatively, a contracting problem between financial intermediaries and the non-financial firms, which receive credits, yields a propagation mechanism in which firms' leverage crucially matters (Carlstrom and Fuerst, 1997; Bernanke, Gertler, and Gilchrist, 1999). Models have also been developed which draw on two-sided financial contracting in which leverage in the real and the financial sector affects macroeconomic dynamics (Kühl, 2014; Hirakata, Sudo, and Ueda, 2011; Sandri and Valencia, 2013 among others).

banks' balance sheets and present the consequences for macroeconomic dynamics. We extend the New Keynesian DSGE model of [Gertler and Karadi \(2011\)](#) by introducing a non-state-contingent asset into banks' balance sheets alongside a state-contingent asset, i.e. banks hold two assets. Thus, we allow for a non-state-contingent asset with a constant price of unity and a state-contingent asset which is traded on a market and consequently exhibits a market-determined price. For this reason we split up capital production into two sectors. Non-state contingency is introduced into our model by assuming that a financial contracting problem exists between the bank and one of the two capital-producing sectors, whereas the resulting loan contract is signed before shocks are realized. The other sector remains financially unconstrained.²

Our results show that the amplification of shocks to the real economy caused by financial frictions in the banking sector is dampened as the weight of non-state-contingent assets in banks' balance sheets increases. In the case of our non-state-contingent assets, firms' net worth makes it possible to sign a financial contract with fixed payments. Since agents agree on contractual payments before shocks are realized and these payments are guaranteed, this debt contract insulates banks' balance sheets from recent economic activity in the absence of defaults. For the dominance of the state-contingent asset, returns and asset prices, which are influenced by the current state of the economy, instantaneously affect banks' balance sheets and then feed back into the real economy. With the dominance of state-contingent assets, the economy becomes more volatile because the banking sector depends on real economic activity to a great extent, which then feeds back into the real sector. We derive our results in a setting which completely abstracts from defaults in order to highlight the implications from the general properties of non-state-contingent assets. Considering defaults in debt contracts is beyond the scope of this paper.³

The paper is organized as follows. Section 2 provides a description of the model. Before dynamics are discussed in Section 4, we briefly present the calibration in Section 3. Section 5 concludes.

2 Model

We draw on a New Keynesian dynamic stochastic general equilibrium model developed by [Gertler and Karadi \(2011\)](#). We modify this model in one particular respect: We introduce in addition to the state-contingent a non-state-contingent asset. For doing so, we assume that there are two different capital-producing sectors, whereas one of them - the new one - is exposed to a financial contracting problem. In this sector, entrepreneurial capital producers take non-state-contingent loans from banks. Furthermore, banks finance the activity of the other capital-producing sector by buying state-contingent assets traded on a market. Capital is used for the production of intermediate goods. With the help of retail firms the intermediate goods are transformed in final goods. Retail firms are also responsible for sticky prices.

²This setting is similar to [Fisher \(1999\)](#), whereas our contracting problem is different from his.

³Defaults are considered in [Kühl \(2014\)](#) or [Rannenberg \(2013\)](#), for example.

2.1 Households

As in [Gertler and Karadi \(2011\)](#), there is a continuum of households with mass of unity, in which a share f^B of each household becomes bank managers who operate a bank. Every period the probability of returning to the household sector is p^B . Similarly, a share of f^E becomes entrepreneurial capital manufacturers, with the remaining share $1 - f^B - f^E$ supplying its labor to intermediate goods producers. Entrepreneurial capital manufacturers also return with a fixed probability of p^E to the household sector. If both bankers and entrepreneurial capital manufacturers leave the household they obtain an endowment, and if they return to the household sector they transfer their remaining assets, but there is no regular transfer inbetween. In the continuum of households, every household h has preferences over consumption $C_{h,t}$ and labor $N_{h,t}$ and maximizes lifetime utility

$$\max E_t \sum_{i=0}^{\infty} \beta^i \left[\ln (C_{h,t+i} - h^C C_{h,t+i-1}) - \frac{\chi}{1+\varphi} N_{h,t+i}^{1+\varphi} \right]. \quad (1)$$

The parameter $\varphi > 0$ is the inverse Frish elasticity and $\chi > 0$ is for scaling purposes, while β reflects the time preference. The expression E_t denotes the expectations operator at time t . Households exhibit habit formation, whereas h^C is bounded between 0 and 1. Their financial wealth is distributed to deposits $D_{h,t}$ and government bonds $B_{h,t}$, which are both denominated in real terms with a maturity of one period. The return on short-term debt over one period is given by the gross real return R_t . The budget constraint can consequently be written as

$$C_{h,t} + B_{h,t} + D_{h,t} = W_t N_{h,t} + R_{t-1} (B_{h,t-1} + D_{h,t-1}) + T_{h,t} + \Pi_{h,t}, \quad (2)$$

where $T_{h,t}$ denotes lump sum taxes and W_t the real wage. Net transfers between both the banking sector and the real sector (retailers and capital producers) and the household sector are covered by $\Pi_{h,t}$. Government bonds are in zero net supply.

The first-order condition for consumption with ϱ_t as the marginal utility of consumption is

$$\varrho_t = (C_t - h^C C_{t-1})^{-1} - \beta h^C E_t (C_{t+1} - h^C C_t)^{-1}, \quad (3)$$

the first-order condition for labor

$$\varrho_t W_t = \chi L_t^{\varrho}, \quad (4)$$

and the Euler equation

$$E_t \beta \Lambda_{t,t+1} R_t = 1 \quad (5)$$

where

$$\Lambda_{t,t+1} \equiv \frac{\varrho_{t+1}}{\varrho_t}. \quad (6)$$

2.2 Capital Production

The economy consists of two different types of capital which are complements. The capital-producing sector consists of capital producers and entrepreneurial capital manufacturers. Capital producers combine investment goods with depreciated capital goods to obtain the new stock of physical capital. Capital producers cannot provide the stock of capital to the intermediate goods producers directly. For this reason, entrepreneurial capital

manufacturers are needed.

Hence, capital-producing firms and the corresponding stock of capital can be split into two groups. The production technology of capital is identical in both sectors. At the end of period t , depreciated physical capital is combined with new investment goods I_t^e to produce the new stock of physical capital K_t^e , where e denotes the groups ($e = S, L$). Flows of net investment I_n^e are related to adjustment costs, the function of which satisfies $f(1) = f'(1) = 0$ and $f''(1) > 0$. The degree of capital's utilization U_t^e can be varied which then affects the depreciation rate δ^e . In a market of perfect competition capital producers maximize profits

$$\max E_t \sum_{\tau=t}^{\infty} \beta^{T-t} \Lambda_{t,\tau} \left\{ (Q_{\tau}^e - 1) I_{n\tau}^e - f \left(\frac{I_{n\tau}^e + I_{ss}^e}{I_{n\tau-1}^e + I_{ss}^e} \right) (I_{n\tau}^e + I_{ss}^e) \right\}, \quad (7)$$

which are redistributed to households, where I_{ss}^e is the steady-state level of investment and Q_t^e is the price for capital which evolves as

$$Q_t^e = 1 + f \left(\frac{I_t^e}{I_{t-1}^e} \right) + \frac{I_t^e}{I_{t-1}^e} f' \left(\frac{I_t^e}{I_{t-1}^e} \right) - E_t \beta \Lambda_{t,t+1} \left(\frac{I_{t+1}^e}{I_t^e} \right)^2 f' \left(\frac{I_{t+1}^e}{I_t^e} \right). \quad (8)$$

The law of motion for both types of capital evolves as

$$K_{t+1}^e = K_t^e + I_{nt}^e,$$

where net investment is defined as $I_{nt}^e = I_t^e - \delta^e (U_t^e) K_t^e$.

The capital of each group is distributed across entrepreneurial capital manufacturers who intermediate the capital to intermediate goods producers. We assume that the grouping of new entrepreneurial capital manufacturers leaving the household sector into the two groups is exposed to a random process with fixed probabilities. The corresponding share always remains the same, while it is not known *ex ante* to which group the new entrepreneurial capital manufacturers are assigned. The first group S is identical to the capital producers in [Gertler and Karadi \(2011\)](#), from which it follows that these firms are financially unconstrained because no financial contracting problem exists. However, there is a financial contracting problem regarding the second group.⁴ Applying the arguments of [Gertler and Karadi \(2011\)](#) to capital producers, we postulate a costly enforcement problem between the type- L firms and their funders, which is why investment projects are financed by a combination of external and internal funds, loans $L_{m,t}$ and entrepreneurial net worth $NW_{m,t}^E$. Hence, each m -th firm in the L -sector is financially constrained. The balance sheet consequently becomes

$$Q_t^L K_{m,t+1}^L = L_{m,t} + NW_{m,t}^E.$$

Firm managers maximize the terminal wealth of their firms

$$V_{m,t}^E = \max_{\{K_{m,t}^L, L_{m,t}\}} E_t \sum_{i=0}^{\infty} (1 - p^E) (p^E)^i \beta^{i+1} \Lambda_{t,t+1+i} NW_{m,t+1+i}^E. \quad (9)$$

⁴This setting is similar to [Fisher \(1999\)](#), who combines a costly state verification problem with unconstrained firms.

The contracting problem results from the fact that firm managers divert a fraction λ^E of total assets. The enforcement constraint becomes

$$V_{m,t}^E \geq \lambda^E Q_t^L K_{m,t+1}^L,$$

which states that lenders are only willing to provide funds as long as the repayment is guaranteed by a sufficient franchise value of the firm. The problem can be expressed linearly in quantities and returns

$$\max_{\{K_{m,t+1}^L\}} V_{m,t}^E = \max_{\{K_{m,t+1}^L\}} \vartheta_t^{Rk} Q_t^L K_{m,t+1}^L + v_t^L NW_{m,t}^E. \quad (10)$$

The exact solution for this problem draws on [Gertler and Kiyotaki \(2010\)](#). After optimizing Equation (31) subject to Equation (30), we get the first-order conditions

$$K_{m,t}^L : \vartheta_t^{Rk} = \frac{\mu_t^E \lambda^E}{1 + \mu_t^E} \quad (11)$$

and

$$\mu_t^B : \vartheta_t^{Rk} Q_t^L K_{m,t+1}^L + \vartheta_t^L NW_{n,t}^E \geq \lambda^E Q_t^L K_{m,t+1}^L, \quad (12)$$

where μ_t^E is the Lagrangian multiplier for the enforcement constraint.

With the help of the method of undetermined coefficients we can deduce values for the unknown parameters in Equation (31)

$$\vartheta_t^{Rk} = E_t \beta \Lambda_{t,t+1} \Omega_{t+1}^E (R_{t+1}^{k,L} - R_t^L), \quad (13)$$

$$\vartheta_t^L = E_t \beta \Lambda_{t,t+1} \Omega_{t+1}^E R_t^L, \quad (14)$$

with

$$\Omega_{t+1}^E = ((1 - p^E) + p^E (1 + \mu_{t+1}^E)) \vartheta_{t+1}^L. \quad (15)$$

By combining both first-order conditions we obtain

$$Q_t^L K_{m,t+1}^L = \phi_{m,t}^E NW_{m,t}^E \quad (16)$$

with the leverage ratio

$$\phi_{m,t}^E = \frac{\vartheta_t^L}{\lambda^E - \vartheta_t^{Rk}}. \quad (17)$$

As can be seen from Eq. (17), the leverage ratio of an entrepreneur is related to the (discounted) returns on the assets, the (discounted) costs for external funds, and the share of diversion.

From Eq. (17) it follows that leverage ratios are the same across the entrepreneurial capital manufacturers. For this reason aggregation can be performed simply by integration and summation. Since entrepreneurial capital manufacturers return to their households with a given probability and are replaced by new ones which are endowed by households with a fraction γ^E of assets, the aggregate law of motion for entrepreneurial capital

manufacturers' net worth becomes

$$NW_t^E = (p^E + \gamma^E) R_t^{k,L} Q_{t-1}^L K_t^L - p^E R_{t-1}^L L_{t-1}.$$

The unconstrained firms can solely refinance their project without the need to cumulate net worth because the financial intermediaries' monitoring activities completely prevent misbehavior in the entrepreneurial sector. As a consequence, their investment projects are financed by issuing shares which completely cover their expenses. Since the shares $S_{m,t}$ are covered by the physical amount of capital $K_{m,t}^S$ the price of shares coincides with the price of the capital goods they produce (Q_t^S)

$$Q_t^S K_{m,t+1}^S = Q_t^S S_{m,t}.$$

Aggregation across all entrepreneurs of type- S and type- L can simply be conducted by integration.

2.3 Intermediate Goods Firms

Both types of physical capital are complementarily used for the production of intermediate goods by combining them with labor input N_t in a perfectly competitive market.⁵ The typical Cobb-Douglas production technology is modified and becomes

$$Y_t = A_t \left((U_t^S K_t^S)^{\kappa^S} (U_t^L K_t^L)^{1-\kappa^S} \right)^\alpha (N_t)^{1-\alpha}. \quad (18)$$

The term α is the share of capital utilized in production, while κ^S controls the share of type- S capital in total capital.⁶ A shock to total factor productivity, which follows an autoregressive process with disturbances ϵ_t^A , is captured by the term A_t in Eq. (18)

$$\log(A_t) = \rho^A \log(A_{t-1}) + \epsilon_t^A. \quad (19)$$

By choosing both utilization rates and the labor input, intermediate goods producers maximize their profits at time t , taking the price of intermediate goods P_{mt} , the real wage, and the price of both capital goods as given.

The demand for physical capital of type- S arises as

$$P_t^m \alpha \kappa^S \frac{Y_t}{U_t^S} = \delta'^S (U_t^S) K_t^S \quad (20)$$

and of type- L as

$$P_t^m \alpha (1 - \kappa^S) \frac{Y_t}{U_t^L} = \delta'^L (U_t^L) K_t^L \quad (21)$$

while the demand for labor becomes

$$P_t^m (1 - \alpha) \frac{Y_t}{N_t} = W_t. \quad (22)$$

⁵This modification is in the spirit of [Krusell, Ohanian, Ríos-Rull, and Violante \(2000\)](#).

⁶The modification of the production function is similar to [Kühl \(2014\)](#).

The functions δ'^L and δ'^S are the first derivatives of the depreciation rates for capital which are a function of the corresponding utilization rates. Intermediate goods firms operate on zero profits and allocate their *ex post* return on both types of capital to their owners. The returns on capital $R^{k,e}$ in the type-*S* and type-*L* sectors can be defined as

$$R_{t+1}^{k,S} = \frac{P_{t+1}^m \alpha \kappa^S \frac{Y_{t+1}}{K_{t+1}^S} + Q_{t+1}^S - \delta^S (U_{t+1}^S)}{Q_t^S} \quad (23)$$

and

$$R_{t+1}^{k,L} = \frac{P_{t+1}^m \alpha (1 - \kappa^S) \frac{Y_{t+1}}{K_{t+1}^L} + Q_{t+1}^L - \delta^L (U_{t+1}^L)}{Q_t^L}.$$

2.4 Retail Firms

Nominal price rigidities are introduced into the model, by assuming that a continuum of retail firms, operating in a market of monopolistic competition, purchase intermediate goods before transforming them into a continuum of differentiated goods Y_f . This continuum of differentiated goods is then combined with the help of a CES bundling technology to obtain the final good.

$$Y_t = \left[\int_0^1 Y_{ft}^{(\epsilon-1)/\epsilon} df \right]^{\epsilon/(\epsilon-1)}$$

The degree of substitutability among retailers' output is denoted by ϵ . Each retail firm can set the price for its goods because of monopolistic competition; however, it can only choose the price optimally with a probability of $1 - \gamma$. If firms cannot adjust the price optimally, they follow an indexation rule into which the lagged rate of inflation π_t enters. Retailers maximize profits by choosing the optimal price P_t^* taking the demand for its good and the corresponding price as given:

$$\max E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^i (1 + \pi_{t+k-1})^{\gamma_p} - P_{t+i}^m \right] Y_{ft+i}. \quad (24)$$

The parameter γ_p in Eq. (24) is a measure of price indexation. The first-order condition results as

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^i (1 + \pi_{t+k-1})^{\gamma_p} - \mu P_{t+i}^m \right] Y_{ft+i} = 0$$

with $\mu = \frac{1}{1-1/\epsilon}$ as the price markup. The overall price level emerges as a weighted average of the optimal price and price indexation

$$P_t = \left[(1 - \gamma) (P_t^*)^{1-\epsilon} + \gamma (\prod_{t-1}^{\gamma_p} P_{t-1})^{1-\epsilon} \right]^{1/(1-\epsilon)}.$$

Cost minimization yields the demand for each retailers' good

$$Y_{ft} = \left(\frac{P_{ft}}{P_t} \right)^{-\epsilon} Y_t$$

in conjunction with the price aggregator

$$P_t = \left[\int_0^1 P_{ft}^{1-\epsilon} df \right]^{1/(1-\epsilon)}.$$

2.5 Financial Intermediaries

The economy is populated by a continuum of banks constituting a mass of unity. Each n -th lending bank gives loans to the L -sector ($L_{n,t}$) and buys assets from the S -sector ($S_{n,t}$). The bank's total assets $A_{n,t}^B$ are financed by external and internal funds, debt $D_{n,t}$ with related interest rate R_t and net worth $NW_{n,t}^B$, respectively. Bank's balance sheet becomes

$$A_{n,t}^B = L_{n,t} + Q_t^S S_{n,t}^B = NW_{n,t}^B + D_{n,t}. \quad (25)$$

Non-state contingency is introduced into the model by assuming that the loan contract is signed before the shocks are realized, i.e. the timing for the loan rate R_t^L is $t-1$. Entrepreneurial net worth guarantees the repayment of debt regardless of the state of the economy. In contrast, the return on the other asset depends on the state of the economy. Since state-contingent assets are traded on a market, the balance sheet of the bank is also affected by the price of this asset. The return on total assets R_t^A can be expressed as an average of the loan rate and the return on the state-contingent asset

$$R_t^A = R_{t-1}^L \frac{L_{n,t-1}}{A_{n,t-1}^B} + R_{t-1}^{k,S} \frac{Q_{t-1}^S S_{n,t-1}}{A_{n,t-1}^B}. \quad (26)$$

The reason why there is no contracting problem in the S -sector can be related to monitoring activity which is linked to costs, following arguments by [Goodfriend and McCallum \(2007\)](#). These costs $\Theta_{n,t}^S$ result from holdings of securities relative to total assets and are expressed as shares of net worth

$$\Theta_{n,t}^S = \frac{\tau^S}{2} (\varsigma_{n,t}^S)^2 \quad (27)$$

where $\varsigma_{n,t}^S = \frac{Q_t^S S_{n,t}}{A_{n,t}^B}$, and τ^S is a scaling parameter (similar to [Kirchner and van Wijnbergen \(2012\)](#)).⁷

The law of motion for each bank's net worth (bank capital) becomes

$$NW_{n,t}^B = R_t^A A_{n,t-1}^B - R_{t-1} D_{n,t-1} - \Theta_{n,t-1}^S NW_{n,t-1}^B. \quad (28)$$

Identically to [Gertler and Karadi \(2011\)](#) and our sector- L entrepreneurial capital manufacturers, the lending banks maximize the terminal wealth of their bank $V_{n,t}^B$ by choosing $L_{n,t}$, $S_{n,t}$, and $D_{n,t}$ optimally (Eq. 29).

$$V_{n,t}^B = \max_{\{L_{n,t}, S_{n,t}, D_{n,t}\}} E_t \sum_{i=0}^{\infty} (1-p^B) (p^B)^i \beta^{i+1} \Lambda_{t,t+1+i} NW_{n,t+1+i}^B. \quad (29)$$

⁷This cost function prevents corner solutions. Defining the costs in terms of the share of the non-state-contingent asset does not change the results.

A costly enforcement problem is utilized by assuming that bankers like to divert the fraction λ^B of total assets which cannot be recovered by the depositors. Hence, lending to banks is linked to the terminal wealth of the bank, which induces the incentive constraint to be

$$V_{n,t}^B \geq \lambda^B A_{n,t}^B. \quad (30)$$

Following [Kirchner and van Wijnbergen \(2012\)](#), the optimization in our model is conducted in two steps. In the first step the size of bank's balance sheet is determined, while total assets are taken as given and the composition of the balance sheet is determined in the second step. The economic reasoning behind this approach is that the determination of the balance size and the composition of the balance sheet might be conducted by different divisions in a bank. In our case, this procedure helps to determine bank's portfolio. The terminal wealth of the individual bank, can be expressed linearly in quantities and rates

$$\max_{\{A_t^B\}} V_{n,t}^B = \max_{\{A_t^B\}} v_t^A A_{n,t}^B + v_t^{NW} NW_{n,t}^B. \quad (31)$$

The exact solution for this problem draws on [Gertler and Kiyotaki \(2010\)](#). After optimizing Equation (31) subject to Equation (30) we get the first-order conditions

$$A_{n,t}^B : v_t^A = \frac{\mu_t^B \lambda^B}{1 + \mu_t^B} \quad (32)$$

and

$$\mu_t^B : v_t^A A_{n,t}^B + v_t^{NW} NW_{n,t}^B \geq \lambda^B A_{n,t}^B, \quad (33)$$

where μ_t^B is the Lagrangian multiplier for the enforcement constraint.

With the help of the method of undetermined coefficients we can deduce values for the unknown parameters in Equation (31)

$$v_t^A = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} (R_t^A - R_t), \quad (34)$$

$$v_{n,t}^{NW} = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} (R_t - \Theta_{n,t}), \quad (35)$$

with

$$\Omega_{t+1}^B = ((1 - p^B) + p^B (1 + \mu_{t+1}^B) v_{n,t+1}^{NW}). \quad (36)$$

By combining both first-order conditions we obtain

$$A_{n,t}^B = \phi_{n,t}^B NW_{n,t}^B \quad (37)$$

with bank's leverage ratio $\phi_{n,t}^B$

$$\phi_{n,t}^B = \frac{v_{n,t}^{NW}}{\lambda^B - v_t^A}. \quad (38)$$

The second step of the maximization problem starts from the law of motion for bank's net worth

$$NW_{n,t+1}^B = R_t^L (1 - \varsigma_{n,t}^L) A_{n,t}^B + E \left(R_{t+1}^{k,S} \right) \varsigma_{n,t}^S A_{n,t}^B - R_t A_{n,t}^B - \Theta_{n,t} NW_{n,t}^B \quad (39)$$

which is expressed slightly different. From the maximization problem of the second step,

we obtain a first-order condition that can be rewritten such that

$$\left(E\left(R_{t+1}^{k,S}\right) - R_t^L\right) \frac{A_{n,t}^B}{NW_{n,t}^B} = \tau^S \zeta_{n,t}^S. \quad (40)$$

arises. From the second step in the optimization problem, a positive relationship arises between the spread in returns on assets and the share of securities. The share of securities in bank's balance sheet is related to the (expected) profitability of securities relative to loans.

Eq. (35) still comprises individual characteristics. However, Eqs. (38) and (40) can be combined and solved for $\zeta_{n,t}^S$. It follows that $\zeta_{n,t}^S$ has no individual characteristics any longer and all banks choose the same portfolio composition. Following from Eq. (38), banks therefore choose the same leverage ratio. Since the leverage ratios are all the same across the individual banks, aggregation becomes easy and the aggregate law of motion for banks' net worth can be obtained. Since bank managers return to their households with a given probability and are replaced by new bankers which are endowed by households with a fraction γ^B of banks' assets, the aggregate law of motion for bankers' net worth becomes

$$NW_t^B = (p^B + \gamma^B) R_t^A A_{t-1}^B - p^B R_{t-1}^D D_{t-1}.$$

2.6 Monetary Policy

The central bank sets the interest rate with the help of a standard Taylor rule including interest rate smoothing by responding to the rate of inflation and the output gap.

$$i_t = i_{t-1}^{\rho_i} \left(\frac{1}{\beta} \pi_t^{\kappa_\pi} \left(\frac{Y_t}{Y_t^*} \right)^{\kappa_y} \right)^{1-\rho_i} \exp(\epsilon_t^i). \quad (41)$$

The term ϵ_t^i in Eq. (41) reflects an unexpected monetary policy shock. The Fisher equation is $1 + i_t = R_t E_t(\pi_{t+1})$.

2.7 Market Clearing

In the following equation we present the market clearing condition for our economy

$$\begin{aligned} Y_t &= I_t^S + I_t^L + C_t + G_t \\ &+ f\left(\frac{I_{nt}^S + I_{ss}^S}{I_{nt-1}^S - I_{ss}^S}\right) (I_{nt}^S + I_{ss}^S) + f\left(\frac{I_{nt}^L + I_{ss}^L}{I_{nt-1}^L - I_{ss}^L}\right) (I_{nt}^L + I_{ss}^L), \end{aligned} \quad (42)$$

where the last two terms represent the costs of adjusting the capital stock.

3 Calibration

Regarding the calibration of the model, we predominantly rely on [Gertler and Karadi \(2011\)](#). However, we set the leverage ratio of banks to 6 which is identical to [Gertler and Karadi \(2013\)](#). The spread between the return on capital and the risk-free interest rate in the S -sector is 100 basis points annualized, while the corresponding spread in the L -sector is 150 basis points annualized. We set the spread between the loan rate and the risk-free rate at 25 basis points. For the leverage ratio of entrepreneurial capital manufacturers in the L -sector, we first take a value of 2.4, which is close to the values found in the literature for the non-financial sector in the US (see, for example, [Kalemli-Ozcan, Sorensen, and Yesiltas \(2012\)](#)). Later, we will vary the entrepreneurial leverage ratio to see the impact of its size on the propagation of shocks. The survival rate of entrepreneurs p^E is set to a value which is also used for the bankers, i.e. it becomes 0.972. All other values for the parameters can be found in [Table 1](#).

Table 1: Parameters of the Model

Description	Parameter	Value
Discount rate	β	0.99
Relative utility weight on labor	χ	3.409
Habit parameter	h	0.815
Inverse Frisch elasticity of labor supply	ϕ	0.276
Effective capital share	α	0.33
Elasticity of substitution	ε	4.167
Elasticity of marginal depreciation with respect to utilization rate	ξ	7.2
Inverse elasticity of net investment to price of capital	η_i	1.728
Calvo parameter	γ	0.779
Measure of price indexation	γ_p	0.241
Steady state depreciation rate	δ	0.025
Steady state capital utilization rate	U	1
Fraction of bank capital that can be diverted ($\kappa^S = 0.01, \kappa^S = 0.99$)	λ^B	0.194, 0.346
Proportional transfers to entering bankers ($\kappa^S = 0.01, \kappa^S = 0.99$)	γ^B	0.0022, 4.12×10^{-4}
Survival rate of the bankers	p^B	0.972
Fraction of entrepreneurial capital that can be diverted	λ^E	0.584
Proportional transfers to entering entrepreneurs	γ^E	0.0037
Survival rate of the entrepreneurs	p^E	0.972
Inflation coefficient of the Taylor rule	κ_π	1.5
Output gap coefficient of the Taylor rule	κ_y	0.125
Smoothing parameter of the Taylor rule	ρ^i	0.8
Steady state proportion of government expenditures	G_{ss}	0.2
Autoregressive parameter for total factor productivity shock	ρ^A	0.95

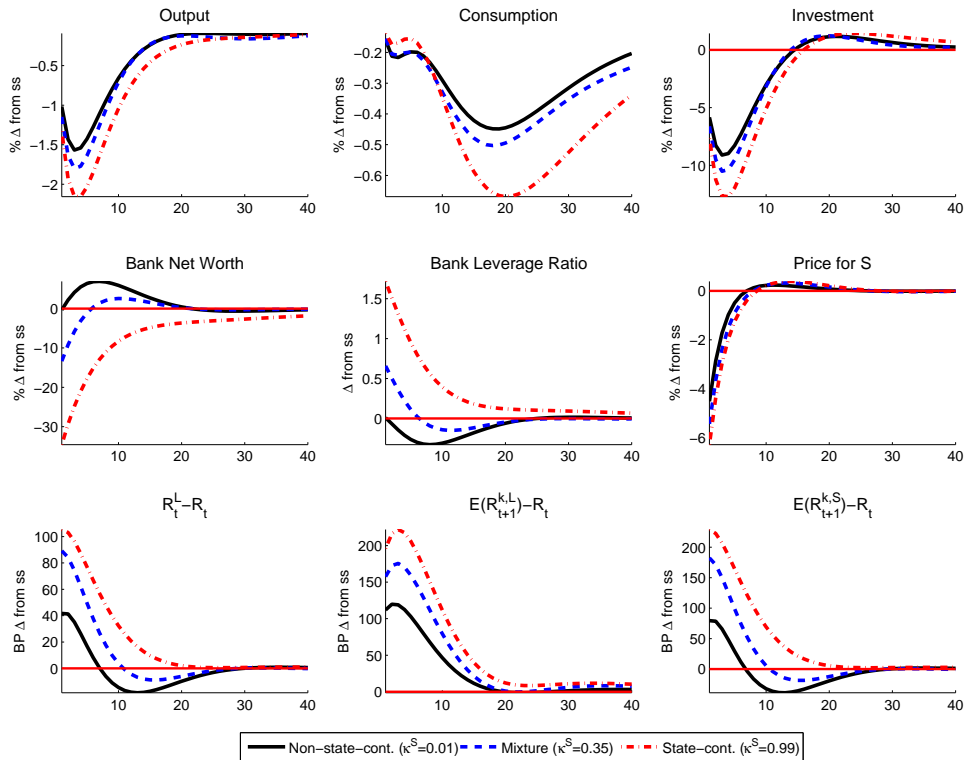
In the next subsection, we vary the share of state-contingent assets in banks' balance sheets. Since spreads are different in both sectors, this variation will also have an effect on the fraction of bank capital that can be diverted and on the proportional transfers to entering bankers. Both parameters are pinned down by the calibration. In [Table 1](#) we present values for two cases, the dominance of non-state-contingent assets ($\kappa^S = 0.01$) and the dominance of state-contingent assets ($\kappa^S = 0.99$).

4 Dynamics

4.1 Effects from Introducing Non-State-Contingent Assets

In this subsection, we investigate the effects on the propagation of shocks resulting from the state contingency of assets. For an evaluation of the model, we compare the responses of selected variables to a monetary policy shock and a shock to total factor productivity. In Figs. 1 and 2 we vary the share of type- S capital in the production function, which also determines the loan-to-security ratio and affects the balance sheets of the banks. The solid black lines give the responses for an economy which is dominated by firms who rely on loans ($\kappa = 0.01$). The dashed red lines with dots accordingly represent the case of a dominance of securities ($\kappa = 0.99$), which is close to the case of [Gertler and Karadi \(2011\)](#), while the blue dashed lines refer to a combination of both.

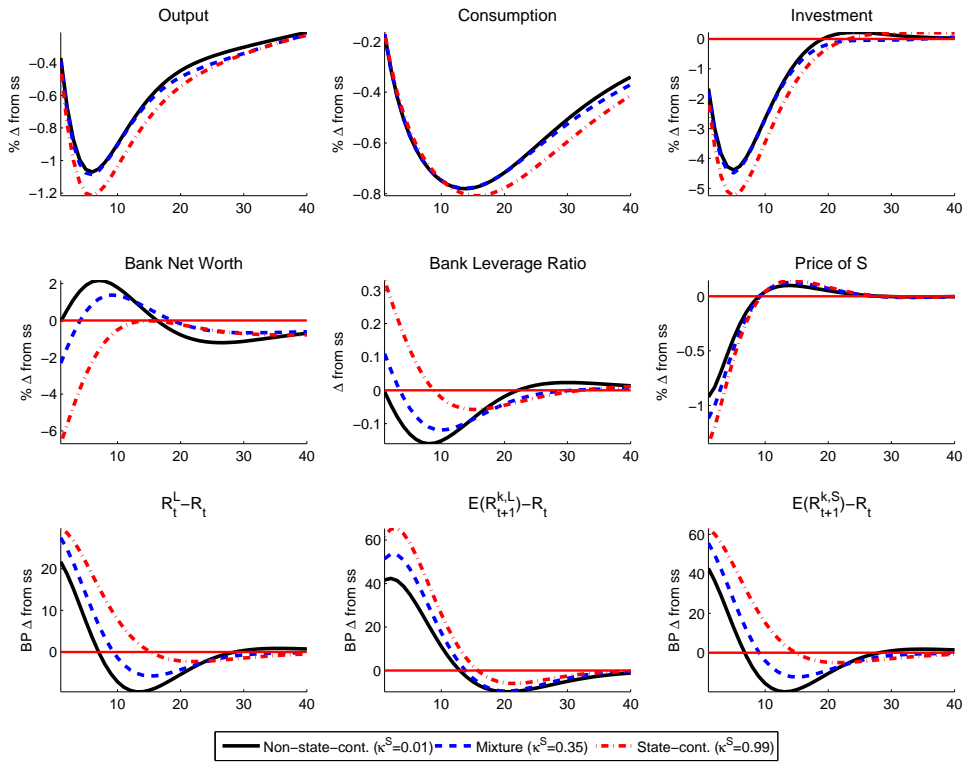
Figure 1: Monetary Policy Shock



Compared to the economy which mainly consists of state-contingent debt, the use of non-state-contingent debt attenuates the responses of consumption, investment, and output following the monetary policy shock (Fig. 1). In the case where state-contingent assets dominate in the economy (and in banks' balance sheets) a contractionary monetary policy shock reduces the price of these assets, which lowers banks' net worth. Since banks' leverage ratio increases as a result while funding costs for banks become more expensive at the same time, the initiated need to delever induces banks to cut their credit supply. The

deterioration in real sector's borrowing conditions then amplifies the fall in investment. In the economy which is dominated by non-state-contingent debt, the drop in the price for capital mainly affects the balance sheets of type- L entrepreneurial capital manufacturers. Although the increase in the policy rate makes debt financing for banks more expensive, banks' net worth is built up. The reason is that the initial cut in credit supply yields an excess demand for credit and bank lending rates rise. However, the effect from the drop in the price for the securities on banks' net worth is negligible; banks can delever by raising net worth. This effect dampens the amplification which results in the case where state-contingent assets dominate. Consequently, an attenuation effect arises which is due to the different response of banks' leverage ratio if non-state-contingent assets play an important role in banks' balance sheets.

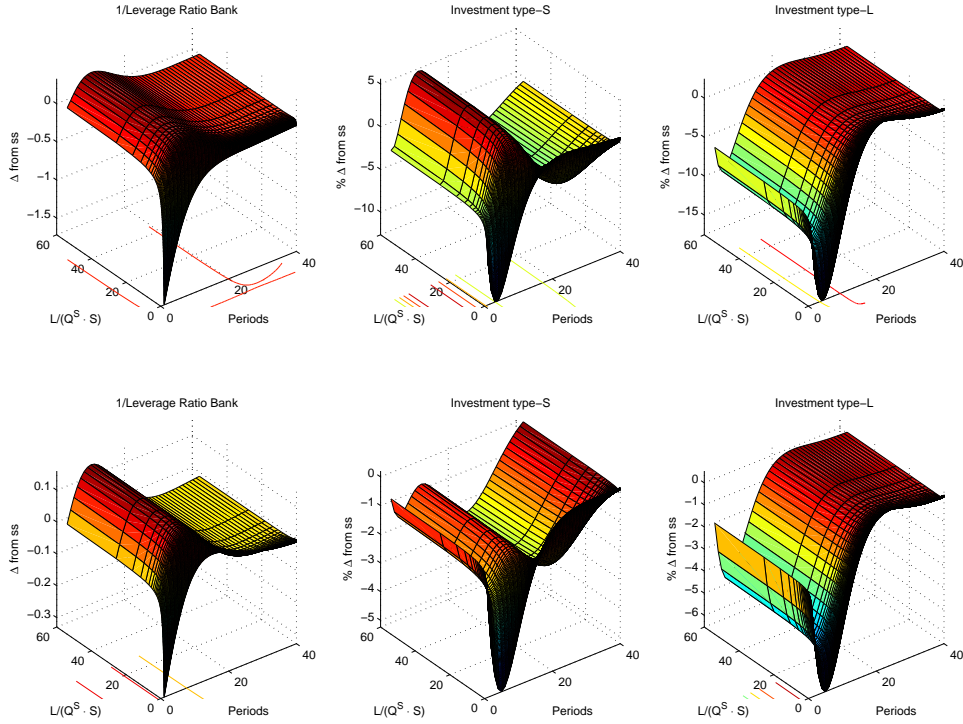
Figure 2: Shock to Total Factor Productivity



A similar effect arises for the shock to total factor productivity (Fig. 2). Where the state-contingent asset is dominant, capital demand is reduced and the rise in inflation as a response to the negative shock to total factor productivity raises the interest rate. The price of capital drops as a consequence which lowers the value of assets in banks' balance sheets and depresses banks' net worth. Since the banks' leverage ratio increases the financial constraint in the banking sector, it becomes more binding. With the dominance of the non-state-contingent asset, the drop in capital prices affects banks' balance sheets to a lesser extent. Because of a deterioration in borrowing conditions, through the rise in the (short-term) interest rate, banks cut their credit supply on impact. Following the

resulting excess demand for credit, lending rates rise and greater profits are generated, helping banks to build up net worth. Since financial constraints are relaxed due to the drop in banks' leverage ratio, the effect on output is attenuated compared to the case in which the state-contingent asset is dominant.

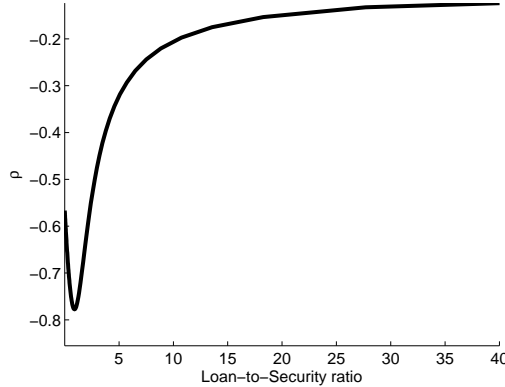
Figure 3: Response of Sectoral Investment to Monetary Policy Shock (first row) and to Total Factor Productivity Shock (second row)



A deeper insight into the attenuation effect can be obtained by looking at sectoral investment (Fig. 3). On the one hand, investment in the L -sector contracts more strongly if the state-contingent asset is dominant. This is related to the fact that asset price changes and reductions in the return on the S -sector asset affects banks' profits more strongly. On the other hand, investment in the S -sector is reduced for the same reason if this sector dominates (case from [Gertler and Karadi \(2011\)](#)) but slightly improves with a rising share of loans. This is related to the drop in banks' leverage ratio if the non-state-contingent asset starts to dominate. In this respect the additional financial constraint in the L -sector plays a role. The build up of entrepreneurial net worth allows banks to sign non-state-contingent contracts because losses of entrepreneurs can be compensated. This has two effects: on the one hand, investment in the L -sector depends on the change in entrepreneurial leverage rather than changes in banks' leverage. On the other hand, banks' returns do not depend on the current state of the economy any longer which means that banks are insulated from current economic activity. Both effects together dampen the propagation of shocks. Investment in the S -sector is driven by banks' leverage ratio

because the contracting problem between banks and their funders is the only issue that matters in this respect. For this reason, investment in the S -sector even increases following a monetary policy shock or a shock on total factor productivity if the non-state-contingent asset dominates.

Figure 4: Correlation Between Output Growth and Banks' Leverage Ratio by Varying the Loan-to-Security Ratio



Both types of shocks discussed above change the sign of the response of banks' leverage ratio by altering the share of non-state-contingent assets. By observing real data, banks' leverage ratio is procyclical (see, for example, [Adrian, Colla, and Shin, 2013](#)). As can be seen in our model, banks' leverage ratio becomes less countercyclical with the dominance of non-state-contingent assets (see Fig. 4).⁸ The reason for this result in our model is that banks are better insulated from the state of the economy. The absence of any effects of changes in the asset's market price contributes to the stabilization in banks' balance sheets. Changes in lending conditions mainly affect banks' profits and, as a consequence, banks' leverage ratio by building up net worth.

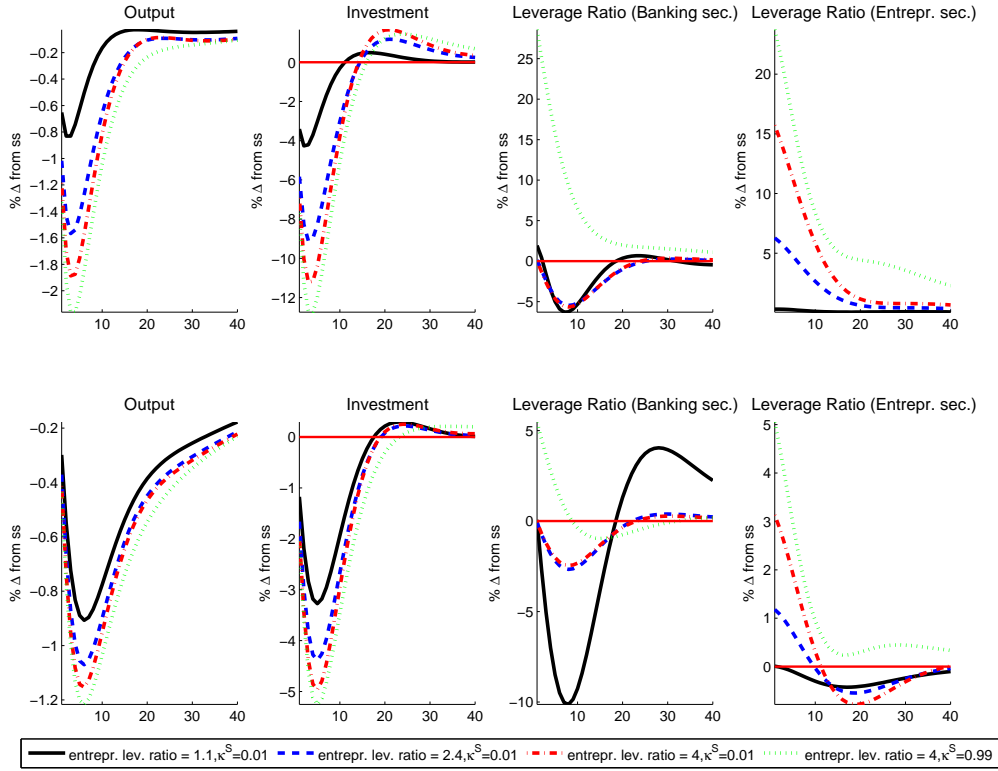
4.2 Role of the Size of the Entrepreneurial Leverage Ratio

In the previous section, we discussed how the state contingency of banks' assets affects the propagation of shocks. We started from a value for the entrepreneurial leverage ratio which reflects the experience in the US. As argued, the results are predominantly driven by a different dynamic of banks' leverage. In this subsection, we show how the propagation of shocks changes if we change the entrepreneurial leverage ratio in the steady state. In Fig. 5, we present the responses of output, investment, banks' leverage ratio, and the leverage ratio in the L -sector to a monetary policy shock (first row) and a shock to total factor

⁸Our results are far away from values observed in reality. However, we provide a very stylized model and can show with its help the general implications. [Rannenberg \(2013\)](#), for example, can achieve values consistent with reality by allowing for defaults in a one-sector model which combines a costly state verification problem following [Bernanke et al. \(1999\)](#) with a costly enforcement problem as outlined by [Gertler and Karadi \(2011\)](#). A positive correlation might be achieved by a different calibration strategy in our case.

productivity (second row) for the case in which the non-state-contingent asset dominates in banks' balance sheets, i.e. κ^S is equal to 0.01. The solid black lines show the responses for an entrepreneurial leverage ratio of 1.1 and the red dashed lines with dots of 4, while the blue dashed lines represent the US experience. In addition, for comparison we provide the dynamics for an economy which is dominated by state-contingent assets and exhibits a leverage ratio of 4 in the L -sector (green dotted lines).

Figure 5: Responses to Monetary Policy Shock (first row) and to Total Factor Productivity Shock (second row) for Different Entrepreneurial Leverage Ratios



As we can see, the propagation of shocks is dampened as the entrepreneurial leverage ratio becomes lower. A low leverage ratio means that the entrepreneurs have a significant net worth buffer to compensate unexpected contractions in the returns on their investment projects which could potentially put the repayment of their debt into question. Consequently, financial constraints are less binding. For both, the monetary policy shock and the shock to total factor productivity, the percentage increase in the entrepreneurial leverage ratio is greater for higher steady-state entrepreneurial leverage ratios. Compared to the case in which the state-contingent asset dominates, the amplification is dampened with lower entrepreneurial leverage ratios due to the relative higher net worth buffer by keeping banks' leverage constant (see, for example, [Hirakata, Sudo, and Ueda \(2013\)](#) for a similar argument). The exercise conducted in this subsection supports the results from the previous subsection: holdings of non-state-contingent assets insulate the banking sector from recent economic activity, and the amplification of shocks is attenuated.

5 Conclusion

We demonstrate, by extending the [Gertler and Karadi \(2011\)](#) model, that the mixture of state and non-state-contingent assets in banks' balance sheets is important for the amplification of shocks caused by a financial contracting problem between the banking sector and the creditors of banks. The mixture of state and non-state-contingent assets in banks' balance sheets alters the propagation mechanism of shocks because banks' net worth evolves differently. In the case of state-contingent assets bank capital is highly procyclical because economic activity is directly translated into bank profits by lower asset returns and asset prices. The banking sector then amplifies shocks to the real economy. Since non-state-contingent assets are signed before shocks are realized and their repayment is guaranteed, they insulate banks from the current state of the economy (which is true for performing loans). The need for firms to hold a substantial degree of net worth is relevant for this channel in our model because sufficient net worth guarantees the full repayment of debt. Shocks then predominantly drive the contractual rate of financial instruments signed between firms and banks, which affects the buildup of bank net worth. Bank capital becomes less and banks' leverage ratio more procyclical. The amplification of shocks to the real economy through the banking sector is attenuated. However, we abstract from defaults in our model in order to highlight the general implications of assets' state contingency on the transmission of shocks.

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A Model Equations

Table 2: Model Equations: Real Sector

Non-Linear Model Equations	
Marginal Utility of Consumption	$\varrho_t = (C_t - h^C C_{t-1})^{-1} - \beta h^C E_t (C_{t+1} - h^C C_t)^{-1}$
Euler Equation	$E_t \beta \Lambda_{t,t+1} R_t = 1$
Discount factor	$\Lambda_{t,t+1} \equiv \frac{\varrho_{t+1}}{\varrho_t}$
Labor Supply	$\varrho_t W_t = \chi L_t^{\varrho}$
Price of capital	$Q_t^e = 1 + f\left(\frac{I_t^e}{I_{t-1}^e}\right) + \frac{I_t^e}{I_{t-1}^e} f'\left(\frac{I_t^e}{I_{t-1}^e}\right) - E_t \beta \Lambda_{t,t+1} \left(\frac{I_{t+1}^e}{I_t^e}\right)^2 f'\left(\frac{I_{t+1}^e}{I_t^e}\right)$
Capital Adjustment Costs	$\Psi_t^e = (I_{nt}^e + I_{ss}^e) \frac{v^s}{2} \left(\frac{I_{nt}^e + I_{ss}^e}{I_{ss}^e + I_{nt-1}^e} - 1\right)^2$
Capital Accumulation	$K_{t+1}^e = K_t^e + I_{nt}^e$
Net Investment	$I_{nt}^e = I_t^e - \delta^e (U_t^e) K_t^e$
Depreciation Rate	$\delta_t^e = \delta_{ss}^e + \frac{v^e}{1+\zeta^e} (U_t^e)^{1+\zeta^e}$
Return on Capital	$R_{t+1}^{k,e} = \frac{P_{t+1}^m \alpha \kappa^e \frac{Y_{t+1}^e}{K_{t+1}^e} + Q_{t+1}^e - \delta^e (U_{t+1}^e)}{Q_t^e}$
Demand for Type-S Capital	$P_t^m \alpha \kappa^S \frac{Y_t}{U_t^S} = \delta^S (U_t^S) K_t^S$
Demand for Type-L Capital	$P_t^m \alpha (1 - \kappa^S) \frac{Y_t}{U_t^L} = \delta^L (U_t^L) K_t^L$
Labor Demand	$P_t^m (1 - \alpha) \frac{Y_t}{L_t} = W_t$
Production	$Y_t = A_t \left((U_t^S K_t^S)^{\kappa^S} (U_t^L K_t^L)^{1-\kappa^S} \right)^\alpha (N_t)^{1-\alpha}$
Intermediate Goods	$Y_t^m = Y_t P_t^{disp}$
Aggregate Price Level	$P_t = \left[(1 - \gamma) (P_t^*)^{1-\epsilon} + \gamma \left(\Pi_t^{\gamma p} P_{t-1} \right)^{1-\epsilon} \right]^{1/(1-\epsilon)}$
Price Dispersion	$P_t^{disp} = \gamma P_{t-1}^{disp} \pi_{t-1}^{-\gamma p \epsilon} \pi_t^\epsilon + (1 - \gamma) \left(\frac{1 - \gamma \pi_{t-1}^{\gamma p (1-\gamma)} \pi_t^{\gamma-1}}{1 - \gamma} \right)^{\frac{-\epsilon}{1-\gamma}}$
Inflation Rate	$\pi_t = \frac{P_t}{P_{t-1}}$
Optimal Price	$P_t^* = P_t \frac{F_t}{Z_t} \frac{\epsilon}{\epsilon-1}$
Numerator	$F_t = P_t^m Y_t + E_t \Lambda_{t+1} \beta \gamma \pi_{t+1}^\epsilon \pi_t^{\gamma p (-\epsilon)} F_{t+1}$
Denominator	$Z_t = Y_t + E_t \Lambda_{t+1} \beta \gamma \pi_{t+1}^{\epsilon-1} \pi_t^{\gamma p (1-\epsilon)} F_{t+1}$
Balance Sheet of Type-L Entrepreneurs	$Q_t^L K_{t+1}^L = L_t + N W_t^E$
Total Entrepreneurial Assets	$Q_t^L K_{t+1}^L = \phi_t^E N W_t^E$
Entrepreneurial Leverage Ratio	$\phi_{m,t}^E = \frac{\vartheta_t^L}{\lambda^E - \vartheta_t^{Rk}}$
Returns on Assets	$\vartheta_t^{Rk} = E_t \beta \Lambda_{t,t+1} \Omega_{t+1}^E \left(R_{t+1}^{k,L} - R_t^L \right)$
Costs for Liabilities	$\vartheta_t^L = E_t \beta \Lambda_{t,t+1} \Omega_{t+1}^E R_t^L$
Discount Factor	$\Omega_{t+1}^E = \left((1 - p^E) + p^E \left(1 + \frac{\vartheta_t^{Rk}}{\lambda^E - \vartheta_t^{Rk}} \right) \vartheta_{t+1}^L \right)$
Net Worth of Type-L Entrepreneur	$N W_t^E = (p^E + \gamma^E) R_t^{k,L} Q_{t-1}^L K_t^L - p^E R_{t-1}^L L_{t-1}$
Balance Sheet of Type-S Entrepreneurs	$Q_t^S K_{t+1}^S = Q_t^S S_t$
Market Clearing	$Y_t = C_t + G_t + I_t^L + I_t^S + \Psi_t^L + \Psi_t^S$
Technology Shock	$\log(A_t) = \rho^A \log(A_{t-1}) + \epsilon_t^A$
Government expenditures	$G_t = G_{ss}$

Table 3: Model Equations: Financial and Policy Sector

Non-Linear Model Equations

Bank's Balance Sheet and Total Bank Assets	$A_t^B = L_t + Q_t^S S_t^B = NW_t^B + D_t$
Return on Total Bank Assets	$R_t^A = R_{t-1}^L \frac{L_{t-1}}{A_{t-1}^B} + R_t^{k,S} \frac{Q_{t-1}^S S_{t-1}^B}{A_{t-1}^B}$
Law of Motion for Bank Net Worth	$NW_t^B = R_t^A A_{t-1}^B - R_{t-1} D_{t-1} - \Theta_{t-1} NW_{t-1}^B$
Bank Portfolio Costs	$\Theta_t^S = \frac{\tau^S}{2} (\varsigma_t^S)^2$
Shares of Assets on Total Bank Assets	$\varsigma_t^S = \frac{Q_t^S S_t^B}{A_t^B}, \varsigma_t^L = \frac{L_t}{A_t^B}, \varsigma_t^S = 1 - \varsigma_t^L$
Total Bank Assets	$A_t^B = \phi_t^B NW_t^B$
Bank Leverage Ratio	$\phi_t^B = \frac{v_t^{NW}}{\lambda^B - v_t^A}$
Returns on Assets	$v_t^A = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} (R_t^A - R_t)$
Portfolio Costs	$v_t^{NW} = E_t \beta \Lambda_{t,t+1} \Omega_{t+1} (R_t - \Theta_{n,t})$
Discount Factor	$\Omega_{t+1} = \left((1 - p^B) + p^B \left(1 + \frac{v_{t+1}^A}{\lambda^B - v_{t+1}^A} \right) v_{t+1}^{NW} \right)$
Portfolio Decision Rule	$\left(E \left(R_{t+1}^{k,S} \right) - R_t^L \right) \frac{A_t^B}{NW_t^B} = \tau^S \varsigma_t^S$
Net Worth of Banks	$NW_t^B = (p^B + \gamma^B) R_t^A A_{t-1}^B - p^B R_{t-1}^D D_{t-1}$
Taylor Rule	$i_t = i_{t-1}^{\rho_i} \left(\frac{1}{\beta} \pi_t^{\kappa_\pi} \left(\frac{X_t}{\epsilon - 1} \right)^{\kappa_y} \right)^{1 - \rho_i} \exp(\epsilon_t^i)$
Fisher Equation	$1 + i_t = R_t E_t (\pi_{t+1})$